Ocean Predict

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Past achievements and ongoing efforts of observing system evaluation by the OceanPredict community

Yosuke Fujii (JMA/MRI)

Elisabeth Remy (MOi)

18 Nov. 2024

1. Close relationship between Observing System Evaluation and OceanPredict

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New Observation always leads ocean prediction progress

◆ Ocean DA for Seasonal Forecasts

- ✓ NOAA/NCEP ⇒ Developed from late 1980s.
- ✓ JMA ⇒ Started from 1999
- ✓ ECMWF ⇒ Calculation started from 1999

◆ Ocean DA for Ocean Predictions

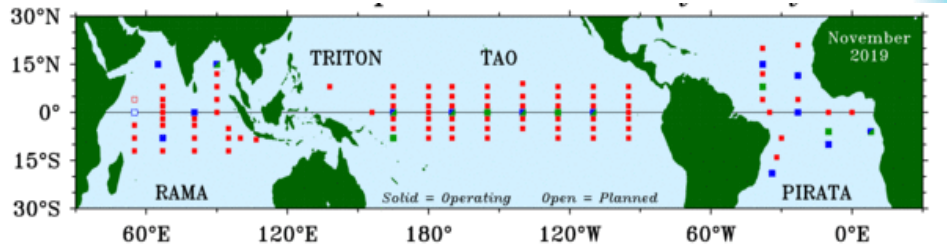
- ✓ JMA (N Pac 1/4˚) ⇒ Developed from late 1990s.
- ✓ US Navy (Glob 1/4˚) ⇒ Calculation from 1997
- ✓ UKMO (Glob 1˚) ⇒ Calculation from 1997
- ✓ French Navy (N Atl. 1/10˚) ⇒ Calculation from 1998

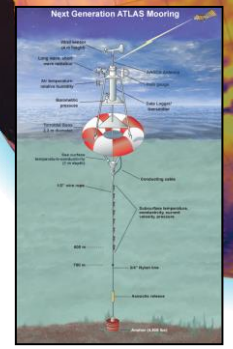
◆ Global Ocean DA Experiment （1998-2008）

GODAE GLOBAL OCEAN DATA ASSIMILATION EXPERIMENT

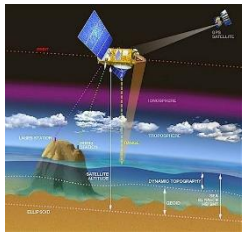
- ☐ Demonstrate feasibility and effectiveness of operational ocean predictions
- ☐ Contribute to ocean prediction progress and the international community

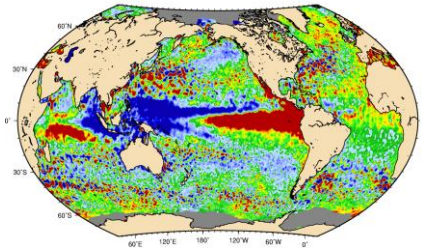
TAO Array is completed



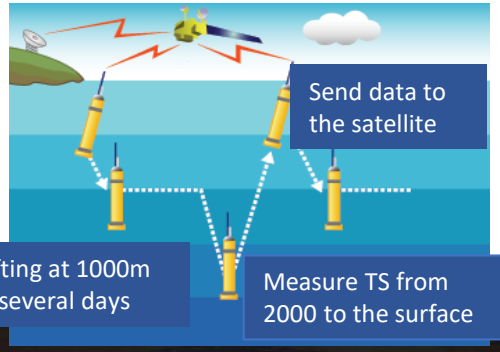


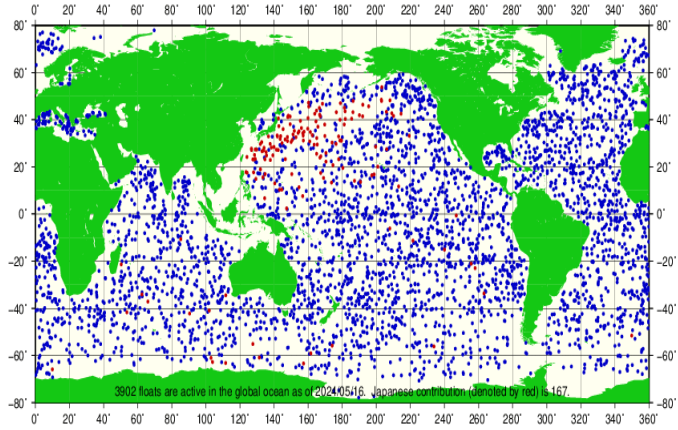
Launch of Altimetry Satellite





Development of Argo Array





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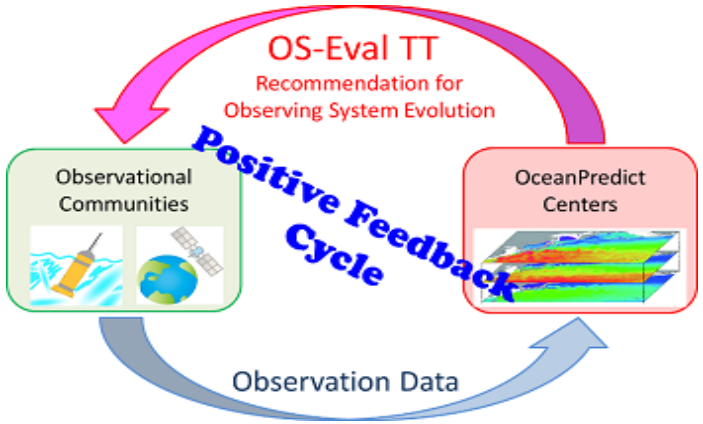
Observing System Evaluation Task Team (OS-Eval TT)

- The launch of GODAE was originally motivated for effective use of satellite altimetry data.
- Clarifying observation impacts in ocean predictions was an essential subject.

GODAE → GODAE OceanView → OceanPredict (Advancing the science of ocean prediction)

- TheTT was took over to GODAE OceanView and OceanPredict.

- GODAE held a workshop for ocean observing system evaluation at UNESCO/IOC in 2007 and formed the OS-Eval TT.



OCEAN OBS'19

- Y. Fujii and E. Remy are the co-chairs since 2017.
- Creating a white paper for OceanObs'19
- Leading the UN Ocean Decade Project SynObs since 2022

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SynObs
UN Ocean Decade Project

2. Examples of Evaluation from past studies

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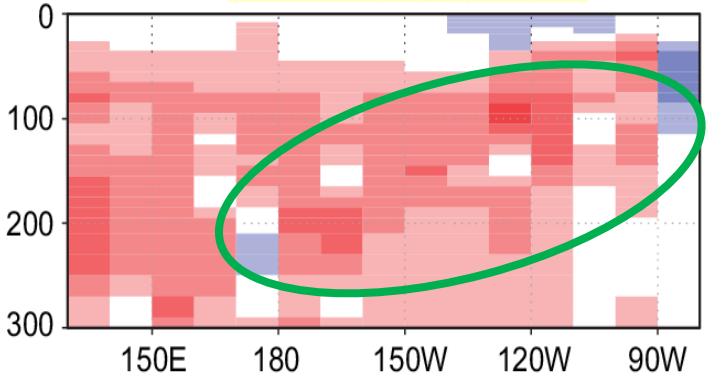
Evaluation of TAO/TRITON Array by OSEs for TPSO2020

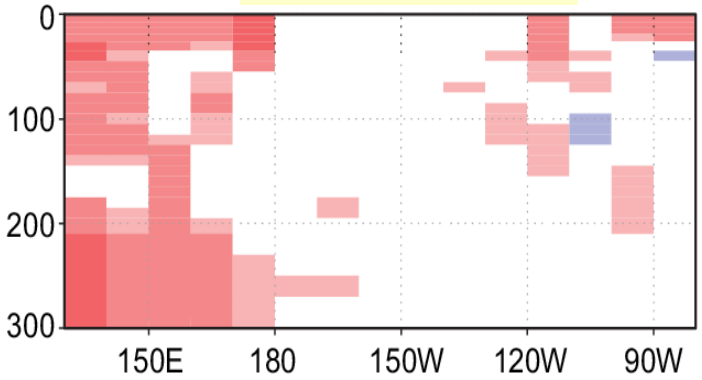
Increase of RMSEs by not assimilated the T/T array data on the global ocean reanalysis (Equatorial Pacific vertical session)

Fujii et al. 2015, JOO

Temperature



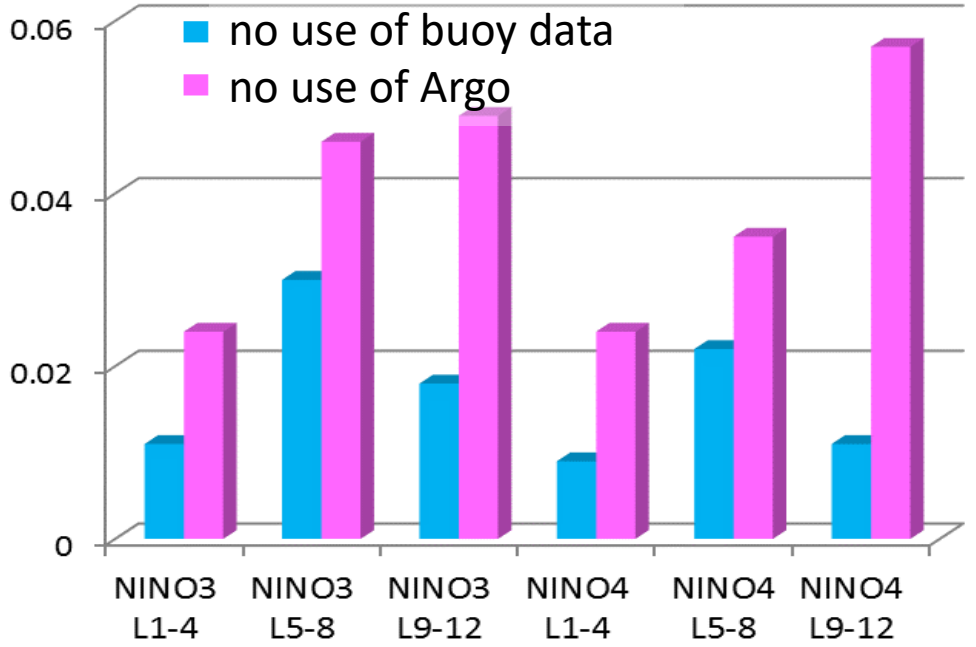
Salinity



- RMSEs are evaluated using non-assimilated Argo data.
- The impact is relatively large on temperature around the thermocline.
- The impact of TRITON buoys on salinity can be seen in the western Pacific. (TAO buoys do not observe subsurface salinity).

Increase of forecasted NINO3/4 index RMSEs in the ENSO forecasts

Fujii et al. 2015, QJRMS

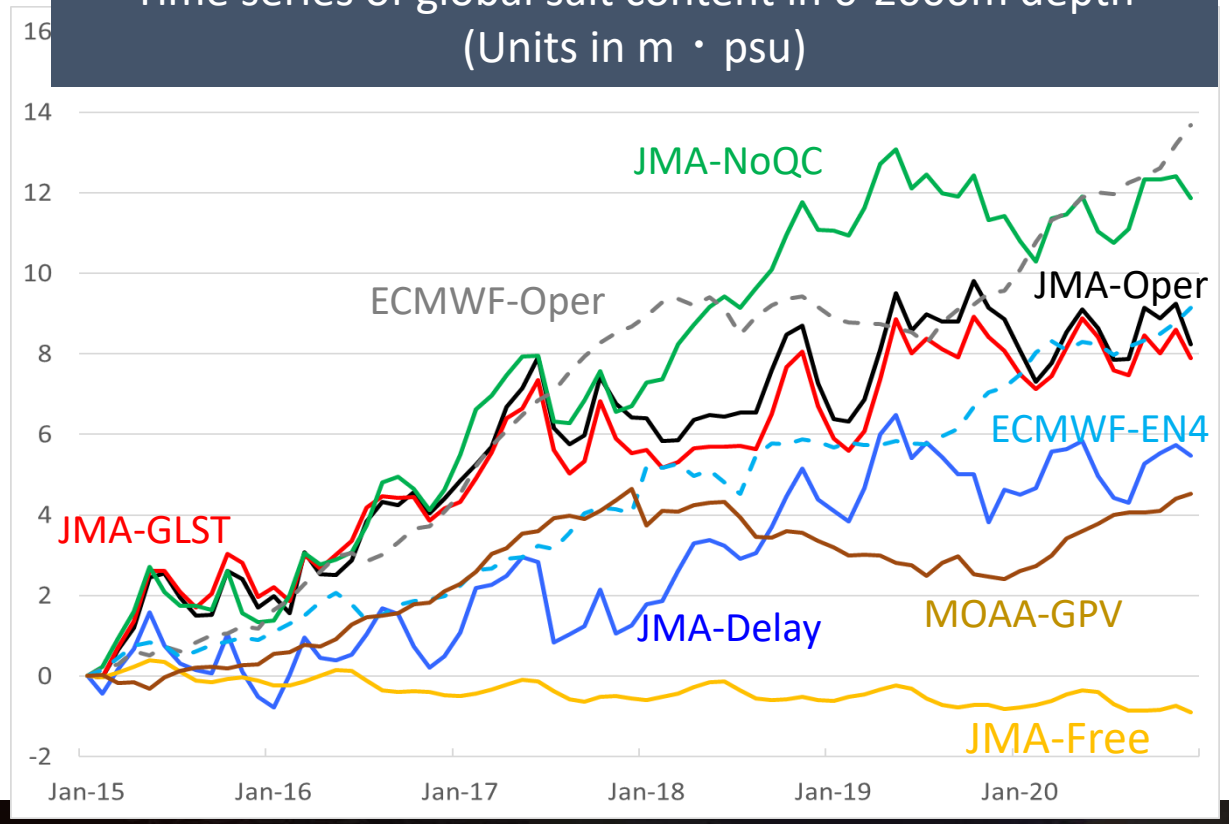


Positive impact of buoy data can be seen for all lead times on both NINO3 and NINO4. (The impact is smaller than the Argo data impact.)

Impact of Argo QC

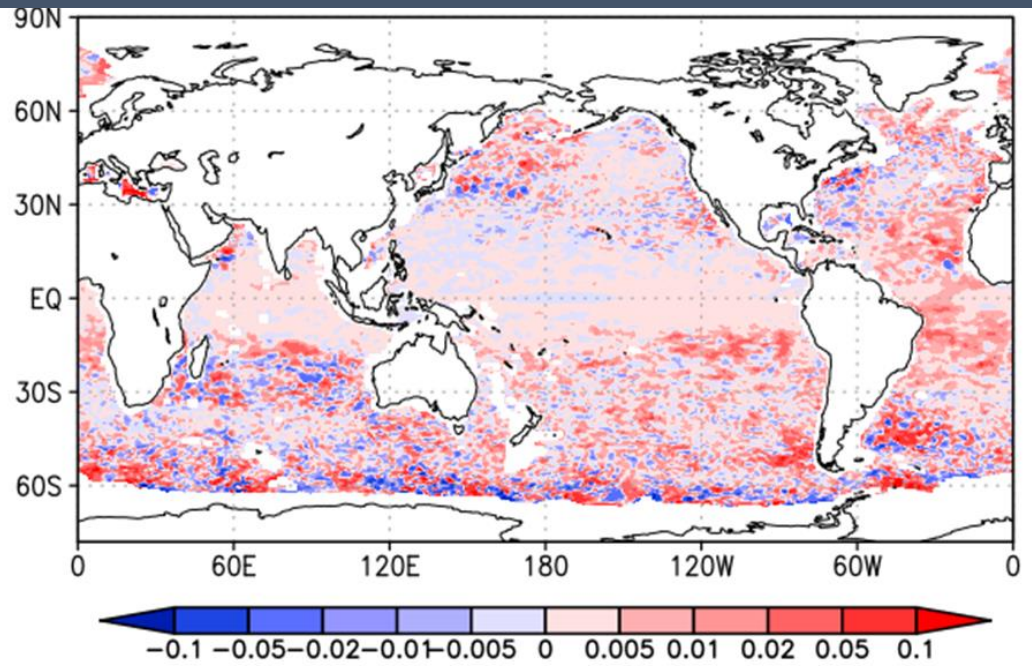
- Argo floats with high salinity drift increases after 2015.
- Coordinated OSEs were conducted in JMA, ECMWF and NERSC to assess the impacts of Argo QC, which removes such float measurements.

Time series of global salt content in 0-2000m depth (Units in m・psu)



Ishikawa et al. 2015, FMARS

Improvement of ACC of SSH temporal variation with satellite altimetry data in JMA-Delay compared to JMA-NoQC



- Global salt content should be conserved, but all OSEs has an increasing trend, as well as objective analyses (incl. MOAA-GPV).
- Real Time QC (applied to the operational data) and delayed-mode QC mitigates the salinity trend.
- Argo QC also improves the consistency of SSH temporal variation, including the increasing trend, with the satellite altimetry data.

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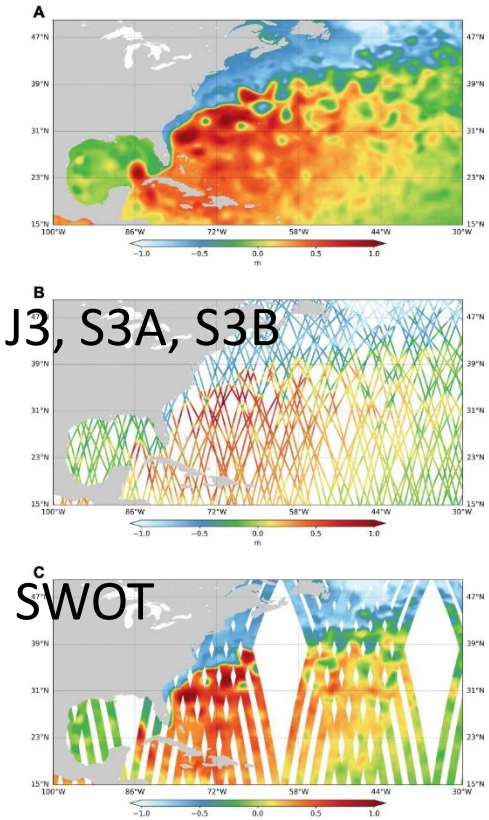
OSSEs for Wide Swath Altimetry observations

- *OceanPredict members have conducted several studies to evaluate the impacts of satellite altimetry observations in ocean predictions.*

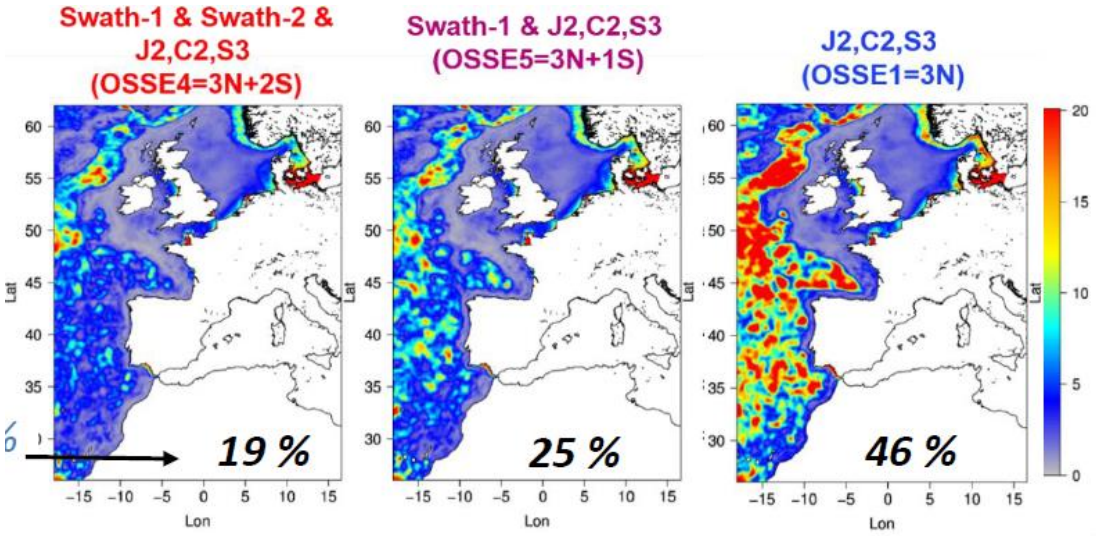


J3, S3A, S3B

SWOT

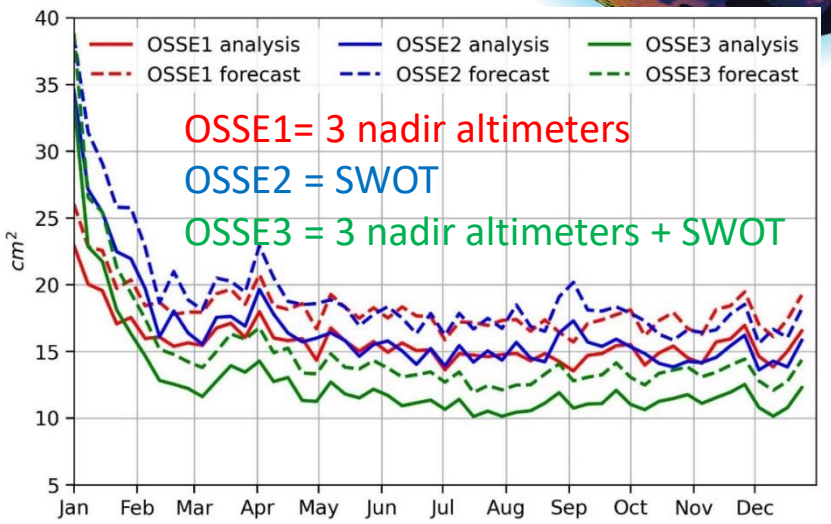
7-day observation coverage

SSH Error variance in cm^2 and ratio of the error to the variance in the nature run



See, Bonaduce and Benkiran, 2018, Ocean Sci.; Tchoang et al.,2021, FMARS; Mounir et al., 2021, FMARS.

Temporal evolution of SSH error variance (in cm^2) for 7-day analysis (plain lines) and forecast (dash lines)



Considering a constellation of 3 nadir (SAR) and SWOT, ocean analysis errors on SSH is reduced by 30% (40% for L>200km) with respect to a 3 nadir constellation.

AtlantOS

EU Horizon 2020 project

Coordinated OSSEs in EU

NATURE RUN

global HR Mercator Ocean - 1/12° - daily (CMEMS)
Forcing: 3h-ECMWF (operational)
Initialisation: EN4 climatology
No assimilation

Synthetic Observations

2-year experiments OSSE

CLS: ARMOR-3D multivariate ocean state (observations only)

CMCC: Ensemble NEMO simulations

Met-Office: 1/4° global - NEMO/ NEMOVAR

Mercator-Ocean: 1/4° global
System: NEMO/SAM2
Forcing: 3h-ERA-Interim
Initialisation: Levitus13 climatology

Observational communities in the EU countries, as well as operational centers, contribute to AtlantOS.

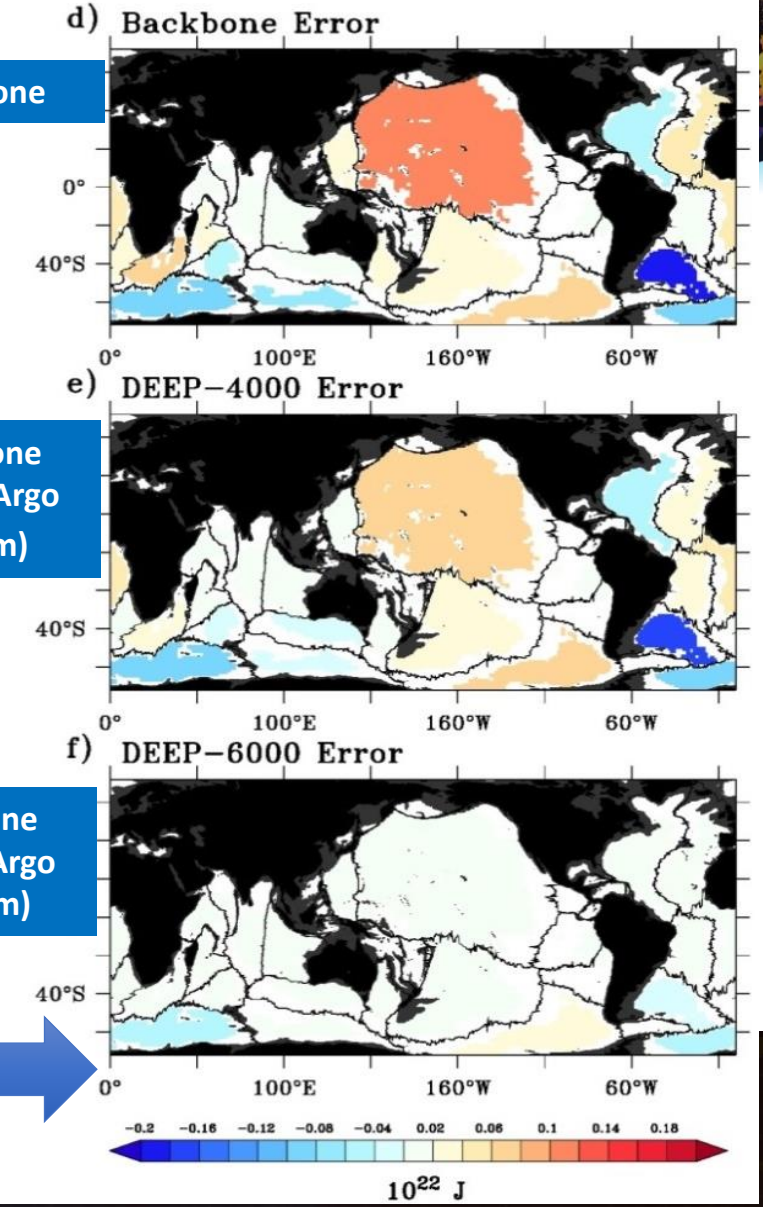
See Gasparin F. et al., J. Climate (2020).
https://doi.org/10.1175/JCLI-D-19-0208.1

Ocean Heat Content error in abyssal oceans (4000-6000 m) in 2010 for the different OSSEs in MOi

Backbone

Backbone + Deep Argo (4000 m)

Backbone + Deep Argo (6000 m)



Use of deep Argo expected to reduce biases in the 4000-6000m layer significantly.

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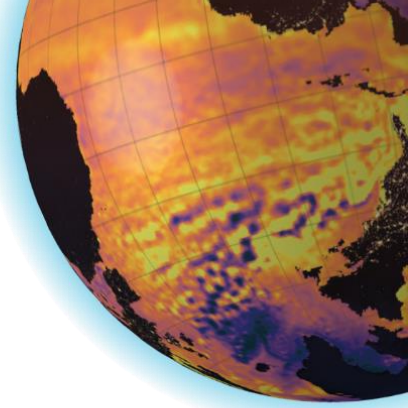
Observation use Information in Ocean Predictions



- OP OS-Eval TT also provides the table summarizing observation platforms from which data are used in each prediction system.
- The simple information demonstrates importance of the platforms and supports to sustain the global ocean observing network.

Table on use of observations in Ocean Prediction Systems (for mooring buoys)

https://oceanpredict.org/observations-use/

Center/ Institute	System Name	Ocean Temp.	Salinity	Velocity (Mech.)	Velocity (ADCP)	Surface Air Temp.	Surface Air Humid.	Surface Wind	Sea Level Pressure	Precip.	Rad.
BoM (CSIRO)	OceanMAPS	Level 5	Level 5		Level 1						
CHM-REMO	RODAS	Level 1	Level 1								
ECCC	GIOPS (global 1/4°)	Level 5	Level 5	Level 1	Level 1	4	4	4	4	4	Level 1
	RIOPS (Pac-Arctic-NAtl 1/12°)	Level 5	Level 5	Level 1	Level 1	Level 4	Level 4	Level 4	Level 4	Level 4	
	CIOPS (East&West Coast, 1/36°)	Level 4	Level 4	Level 1	Level 1	Level 4	Level 4	Level 4	Level 4	Level 4	
ECMWF	OCEAN5 Global 1/4	Level 5	Level 5	Level 1	Level 1			Level 4	Level 4		

3. UN Ocean Decade Project SynObs

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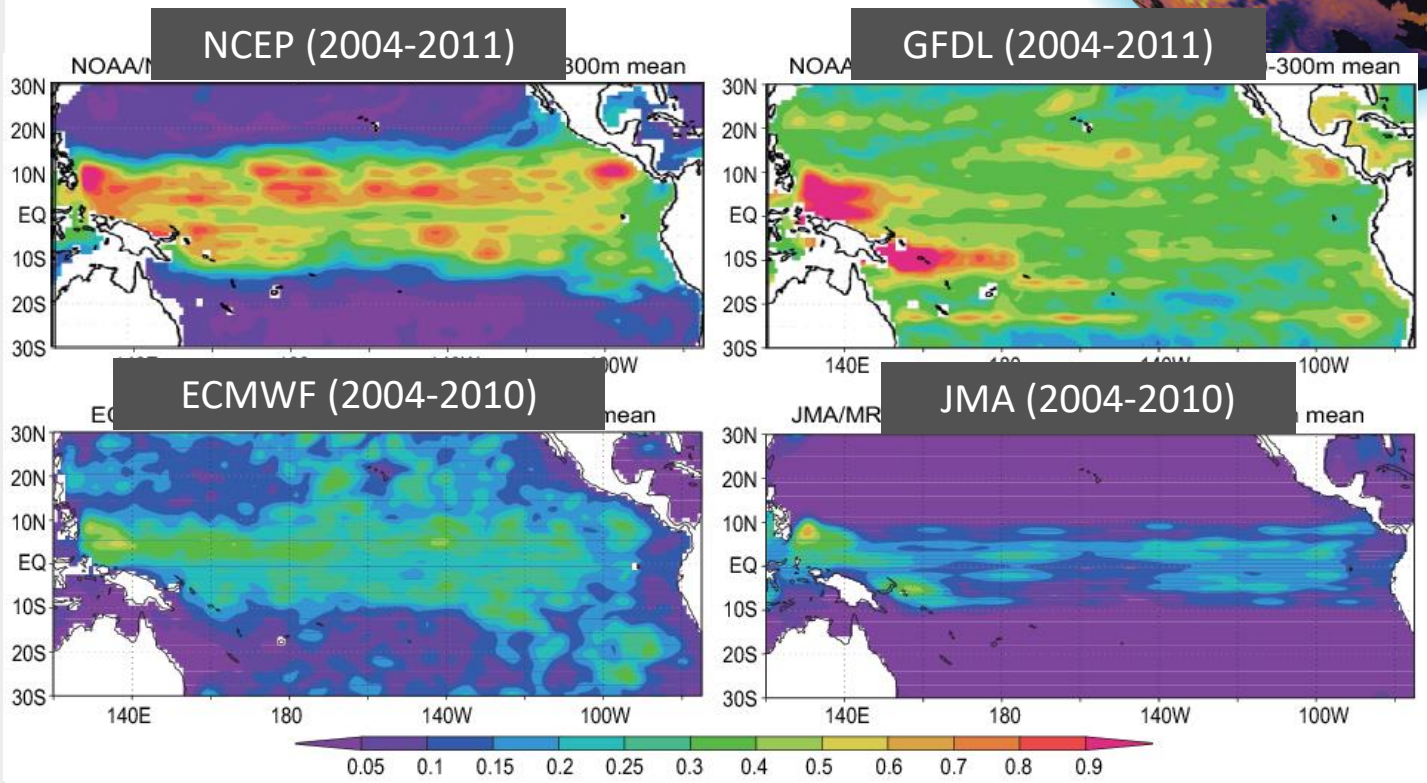
Lessons learnt from past evaluation activities

- Evaluation results inevitably depends on the property and systematic errors (biases) of the prediction systems.
  - Multi-system efforts are indispensable to get reliable evaluation.
- Detailed information on observation platforms and needs of observational specialists should be considered for impactful evaluation.
  - Collaboration with observational community is essential.
- Influence of positive and negative events on the observing network should be informed to the society as soon as possible.
  - Real-time monitoring of observation impacts are highly desirable.

0-300m averaged RMSD of temperature (˚C) between the regular ODA runs and OSE without assimilating tropical mooring buoys



The diversity of the impact among the prediction systems indicates strong dependency on the system.

From Fujii et al., 2015 QJRMS

Synergistic Observing Network for Ocean Prediction

UN Ocean Decade Project

Led by OceanPedict OS-Eval TT

- **Objective**

  SynObs will seek the way to extract maximum benefits from the combination among various observation platforms, typically between satellite and in situ observation data, in ocean predictions.

- **Strategy**

  SynObs aims to identify the optimal combination of different ocean observation platforms through observing system design/evaluation, and to develop assimilation methods with which we can draw synergistic effects.

- **Co-chairs** Y. Fujii (JMA/MRI), Elisabeth Remy (Moi)

SynObs Info.

Contact E-Mail : synobs@mri-jma.go.jp

Webpage: https://oceanpredict.org/un-decade-of-ocean-science/synobs-2/

Mailing List: Request to the contact e-mail for joining

Outline of SynObs activities

1. Collaboration for evaluation and designing

- Coordinating a Multi-System OSE and OSSE (SynObs flagship OSEs/OSSEs)

2. Supporting DA scheme development for better use of observation data

- Share the information through workshops and webs

3. Framework to provide information from ocean prediction systems in real time

- Extension of the observation-use tables and real-time ORA-IP.

4. OS-Eval showcase and reports

- Contributing to WMO Observation Impact Workshop and Rolling Review of Requirements (RRR)
- Frontiers in Marine Science Special Collection

  https://www.frontiersin.org/research-topics/58025/demonstrating-observation-impacts-for-the-ocean-and-coupled-prediction

- Contributing to GOOS (Collaborating in Ocean Observing CoDesign, UN Decade Program)

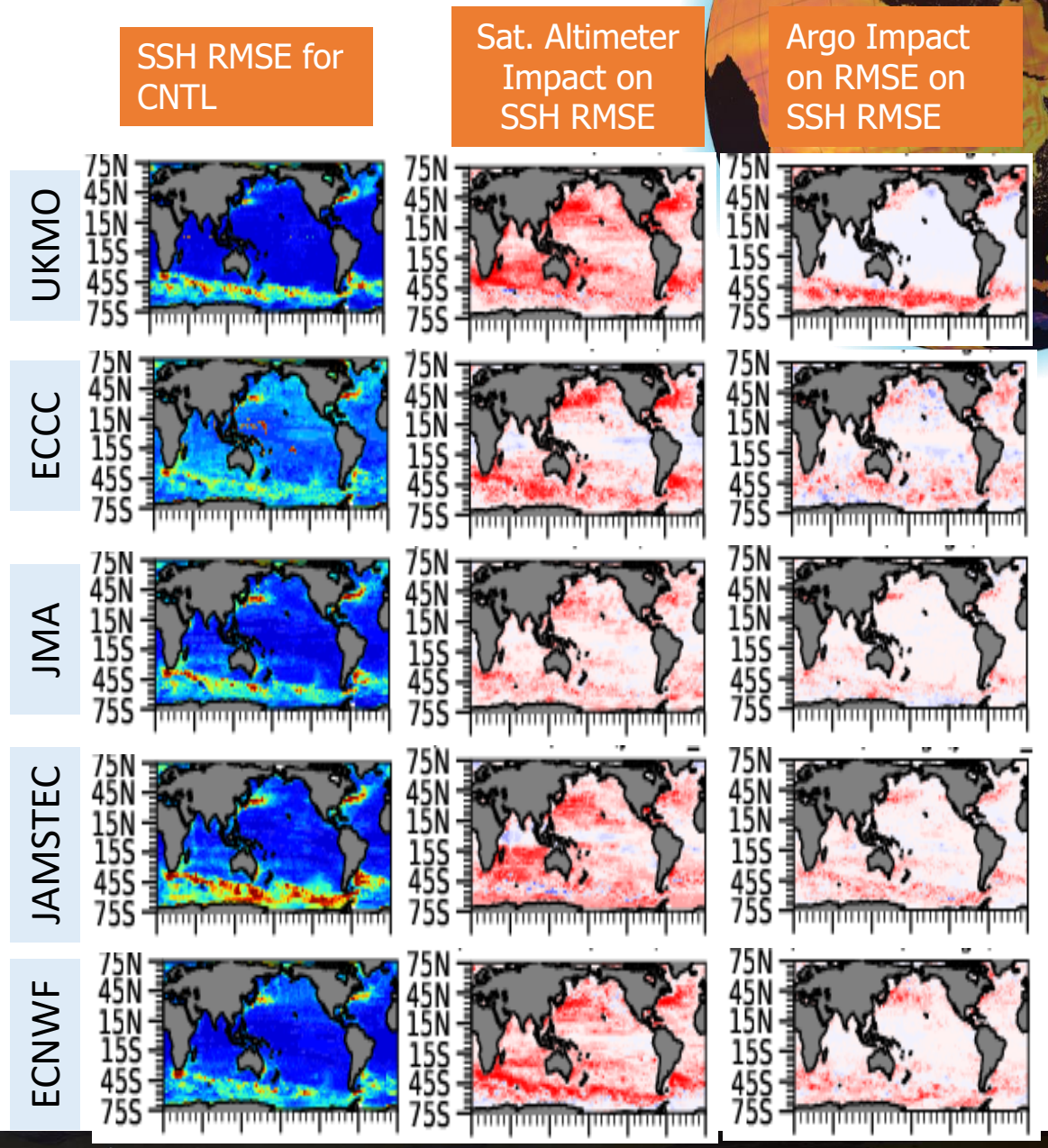
SynObs Flagship OSEs/OSSEs

- Collaborative OSEs/OSSEs using ocean DA and prediction systems with a common setting
- To make robust evaluation which does not depend on a particular system

◆ OP (Ocean Prediction) OSEs
- Use higher-resolution ocean DA and prediction systems.
- Assimilation run for 2020-2022 (at least for 2020)
- 10-day predictions: Started from every pentad

◆ S2S (Subseasonal-to-seasonal) OSEs
- Use coupled prediction systems including lower-resolution ocean DA for oceanic initialization
- Reanalysis run for 2003-2022
- 1-month and 4-month predictions

◆ OP (Ocean Prediction) OSSEs
- Planned for evaluating SWOT, glider observations in coastal and shelf seas, satellite ocean velocity. etc.



Early Result Paper: https://doi.org/10.3389/fmars.2024.1476131

Please also see the presentation by S. Kido (Session 5.3, Tuesday, ROOM IX)

4. Concluding Remarks

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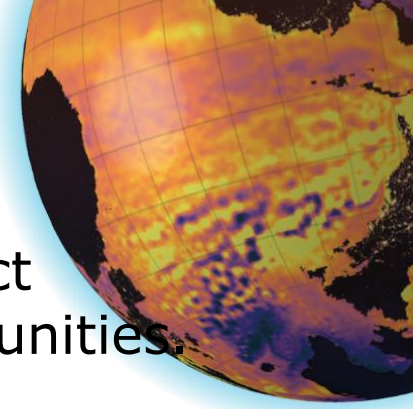
Concluding Remarks



- Close relationship between OceanPredict and OS-Eval
  - ✓ Since observation data are essential for ocean predictions, OceanPredict community should make effective feedback to the observational communities.
- Past achievements of OS-Eval
  - ✓ Importance of various observation data has been demonstrated by various studies to support the maintenance of the ocean observation network.
  - ✓ We learnt several lessons from past activities, (e.g., dependency of evaluation results on the systematic errors of each prediction system must be considered.)
- UN Ocean Decade Project SynObs was launched in 2022
  - ✓ Aim to enhance the collaboration between ocean prediction and observational communities.
  - ✓ The collaborative OSEs/OSSEs activities (SynObs flagship OSE) are on-going to make robust evaluation

SynObs Webpage

European Commission

Copernicus Marine Service

EU4oceanobs
INTERNATIONAL OCEAN GOVERNANCE
EU COMPONENT TO GLOBAL OCEAN OBSERVATIONS

MERCATOR OCEAN INTERNATIONAL

esa

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

Met Office

NERSC

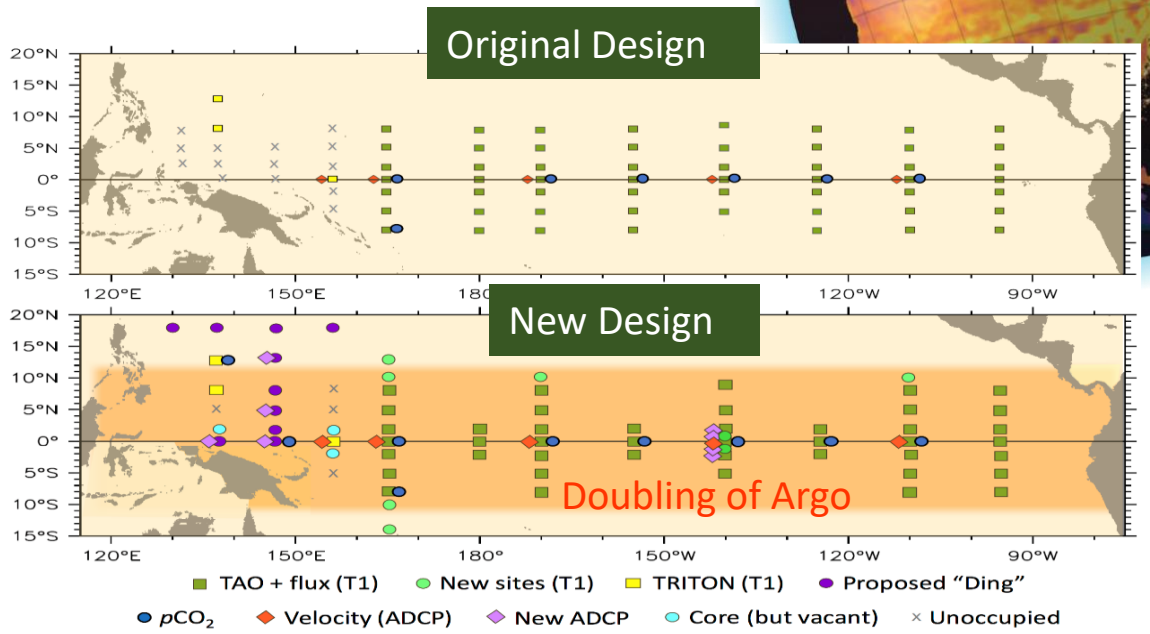
Australian Government
Bureau of Meteorology

Canada

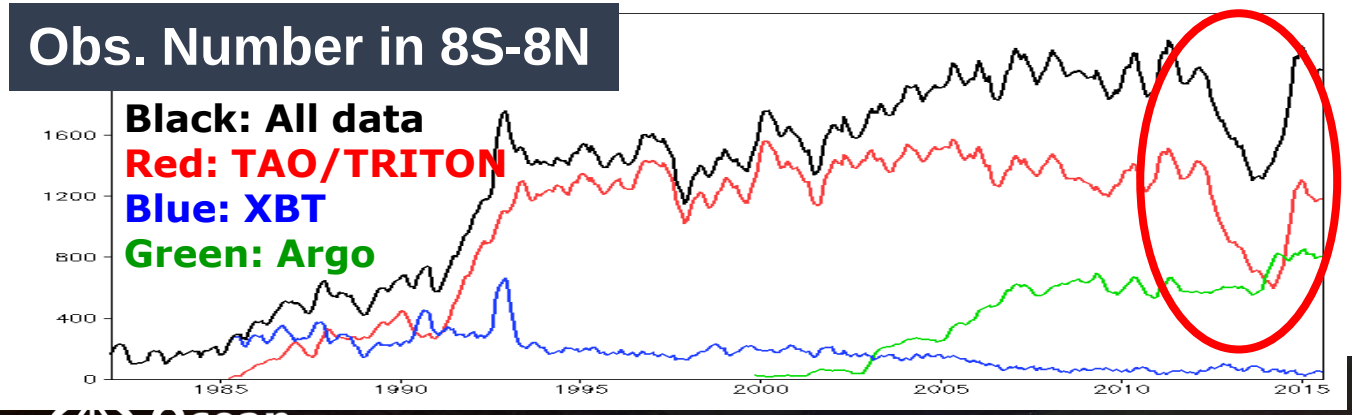
TAO Array Crisis and TPOS2020

TPOS 2020 Tropical Pacific Observing System

- The number of observation data from TAO array severely reduced in 2012-2014.
- TPOS2020 was launched at 2014 to make a efficient and effective design of the Tropical Pacific Observing System (TPOS).
- Publishing white papers of the TPOS2014 workshop, including a paper on the TPOS evaluation from ocean DA perspective (Fujii et al. 2015, QJRMS)
- Publishing first, second, and final reports until 2021.
- The new TPOS design was proposed and the transition is currently on-going.



Obs. Number in 8S-8N



- ✓ Retain all sites at 2°S, 0°, 2°N across the basin
- ✓ Deployment of Chinese "Ding" array.
- ✓ More complete measurements of air-sea flux variables
- ✓ Enhance sampling of the rapidly-varying mixed layer
- ✓ Doubling of the number of Argo profiles in the 10°S-10°N band

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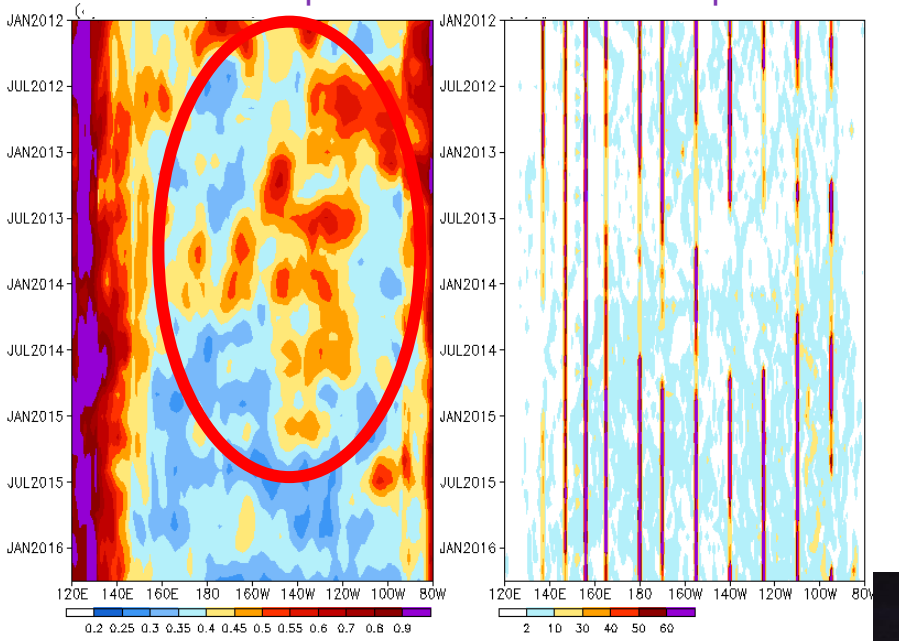
Real-Time Ocean Reanalysis Intercomparison (RT-ORA-IP)

- RT-ORA-IP was started to monitor the TPOS impacts on ocean reanalyses regularly.
- The multi-system ensemble spread becomes larger where the number of observations is small.
- The TAO crisis increased the uncertainty of analysis ocean temperature fields in the central tropical Pacific.
- This is also multi-system evaluation and not depends on a particular system.
- A powerful tool for monitoring the status of TPOS.

Longitude-time section of the ensemble spread of temperature averaged in 0-300m and the number of profiles

2ºS-2ºN

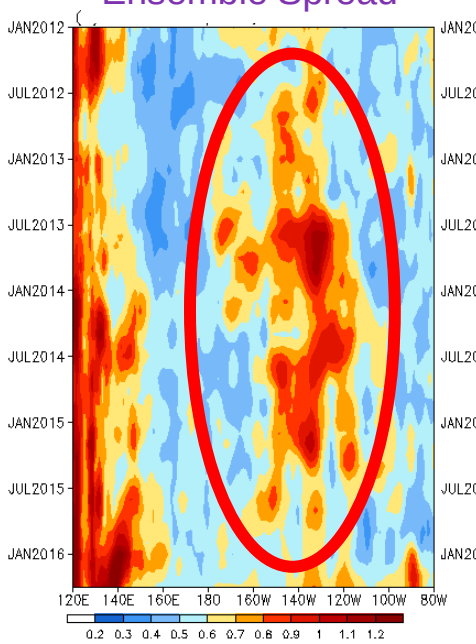
Ensemble Spread



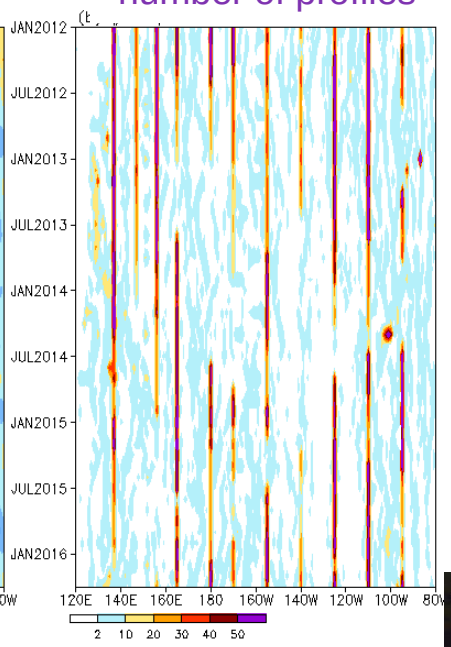
number of profiles

3ºN-8ºN

Ensemble Spread



number of profiles



- 1980-2019, 6 ORAs

https://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

- 1993-2019, 9 ORAs

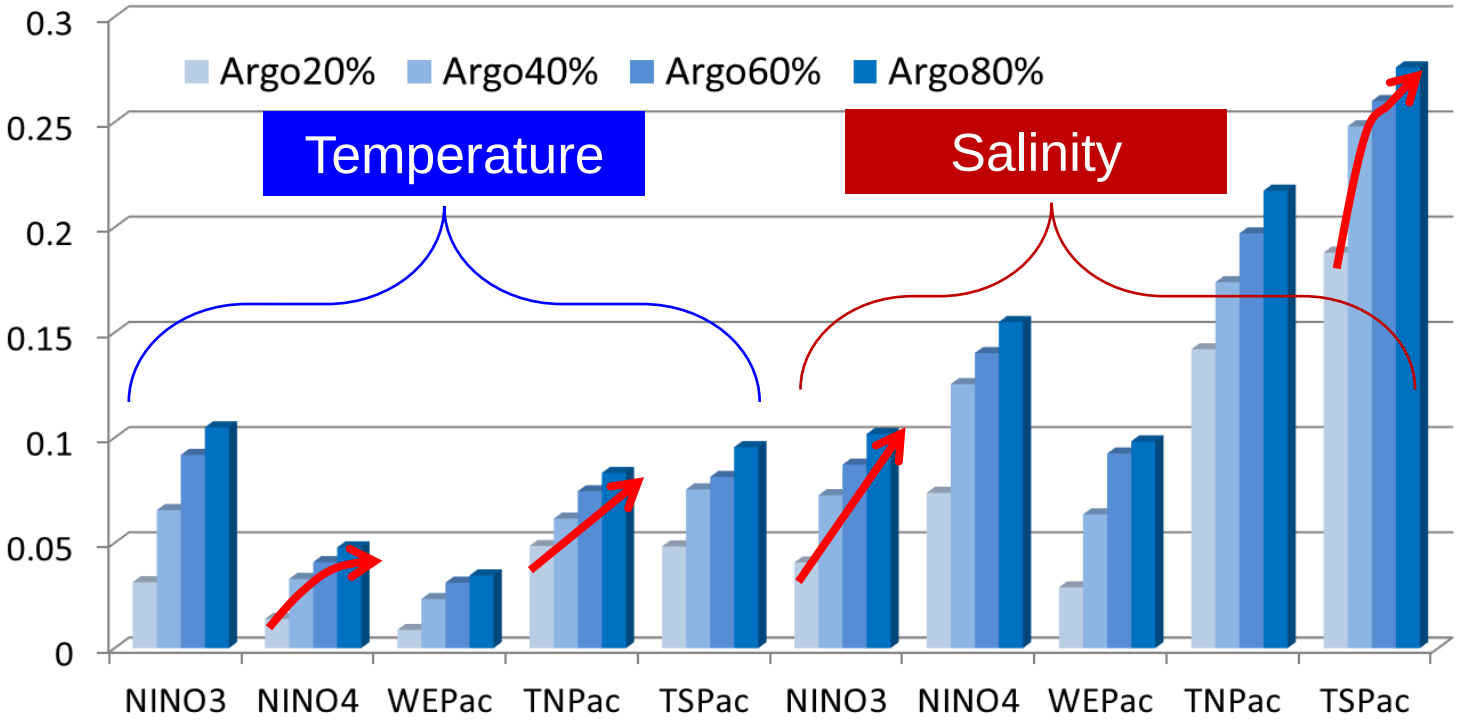
https://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

(NCEP GODAS, JMA, ECMWF, GFDL, NASA, ABOM, MERCATOR, UKMO, MERCATOR, NCEP CFSR)

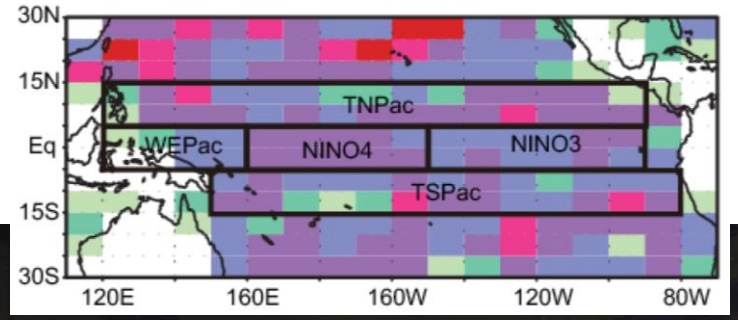
From Xue et al., 2017 Clim. Dyn.

Impact Assessment of Argo float increase

Reduction of TS RMSEs averaged in 0-300m compared to the case where no Argo data are assimilated.



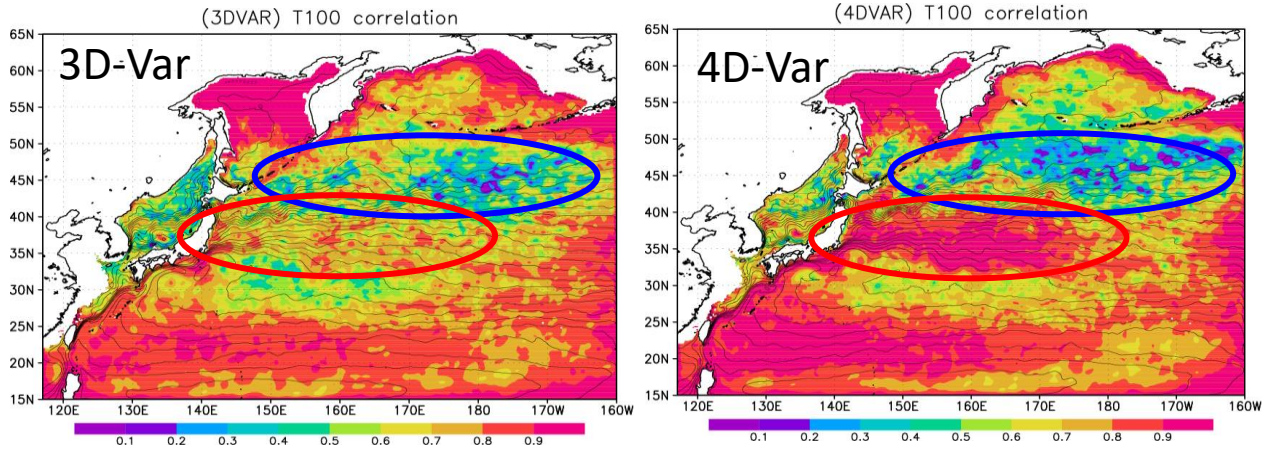
From Fujii et al., 2015, JOO



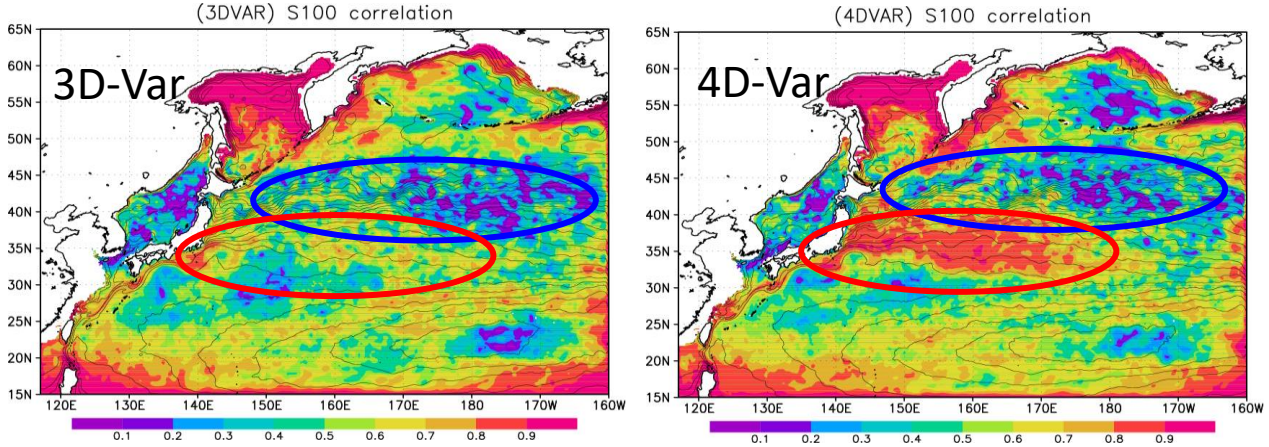
- Current Argo array is designed so that one float is placed in every 3^{o} box.
- The OSEs increasing Argo data being assimilated from 0% to 80% are performed to discuss adequate density of Argo floats.
- RMSEs are evaluated using 20% of Argo not assimilated in all OSEs.
- The RMSEs are reduced almost linearly for TNPac T and NINO3 S.
  - Increasing floats can be effective in these areas.
- In contrast, impacts of Argo tends to be saturated for NINO4 T and TSPac S.

Impact of Argo in the 3D-Var and 4D-Var System

100-m temperature



100-m Salinity

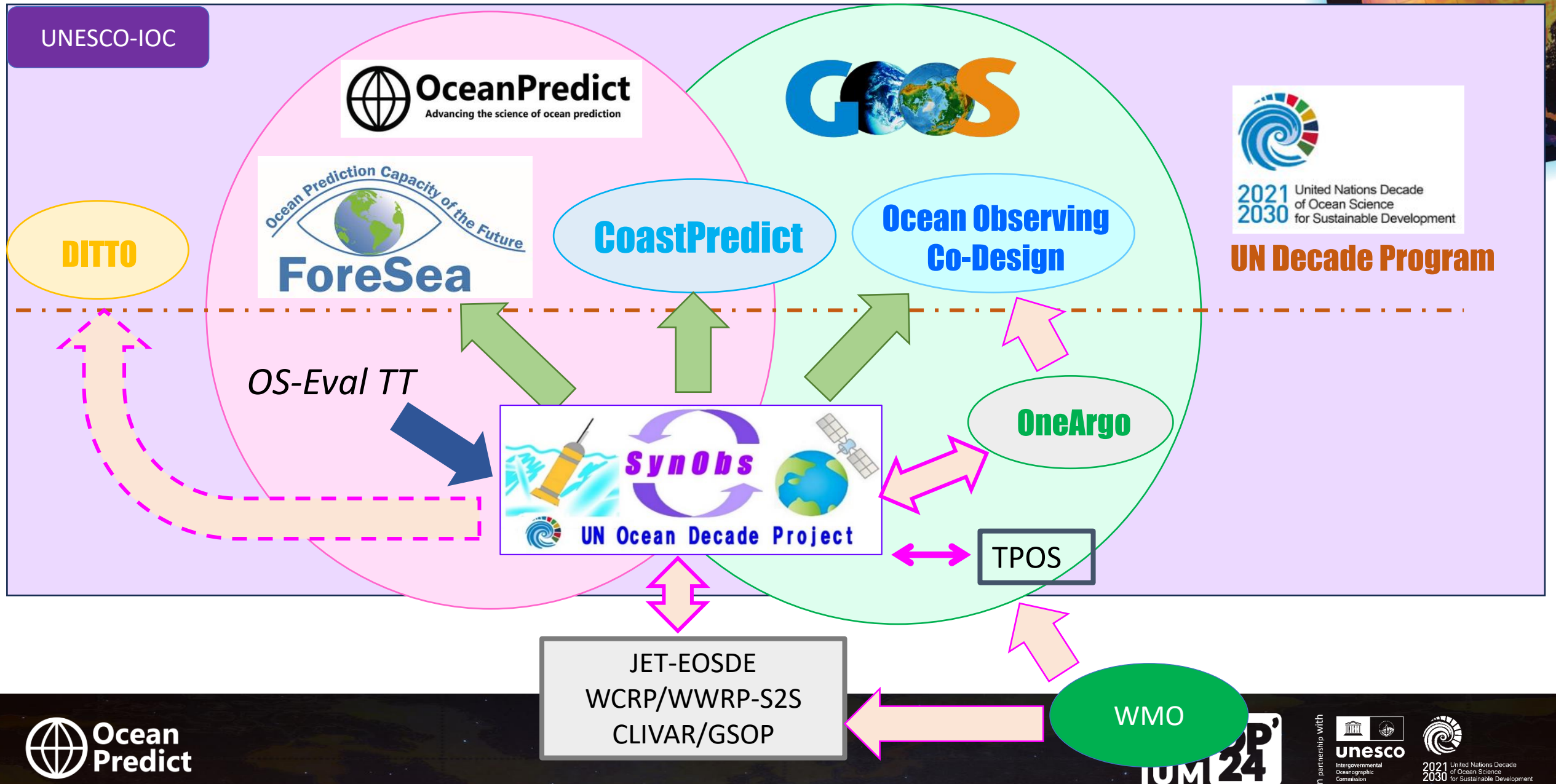


- Argo data generally has a larger impact on the salinity field.
- Large impacts can be seen in the Subarctic region.
- The impact in the Kuroshio Extension area in the 4D-Var system is much smaller than the impact in the 3D-Var system. This is due to the enhanced ability of representing mesoscale eddies from SSH data in the 4D-Var system.
- Thus, **the data impact can be changed with the evolution of the model and data assimilation schemes.**

Correlation of T/S time-series at each grid point between the control run and the OSE run in which Argo data are withheld. A smaller value means that assimilating Argo has a larger impact.

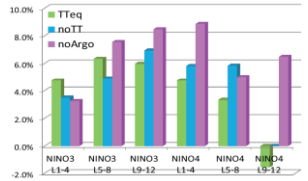
From Fujii et al., 2019, FMS

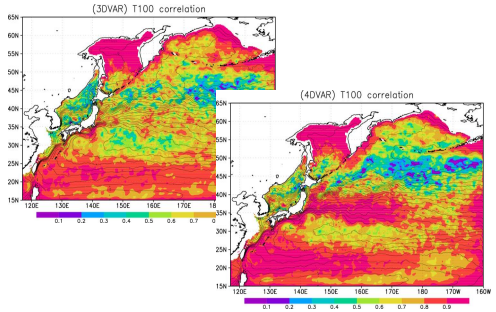
International Collaboration around SynObs



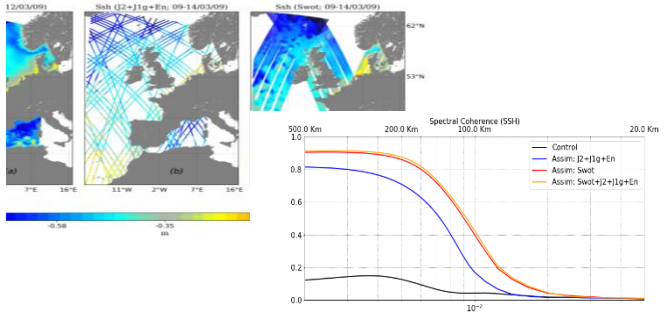
OceanObs'19 CWP on OS-Eval

TPOS and Argo

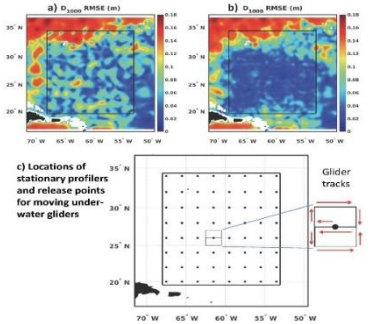




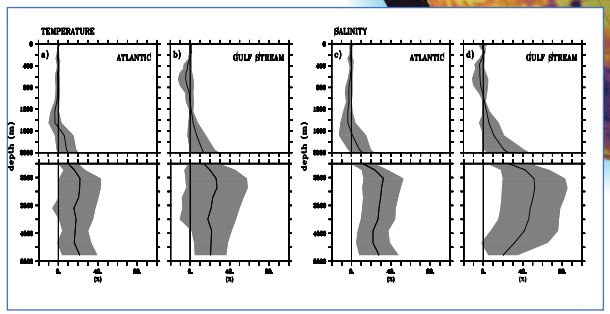
SWOT



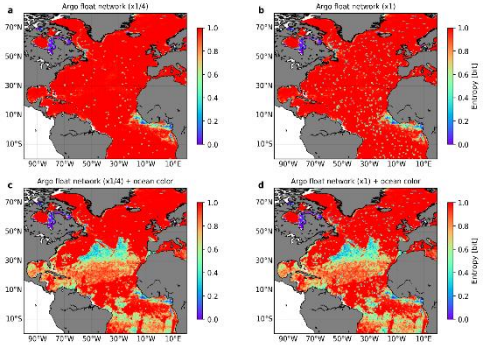
Coastal Obs System



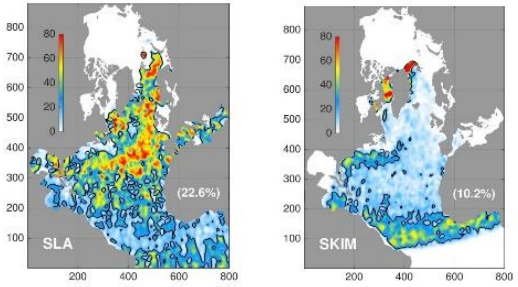
Atlant-OS



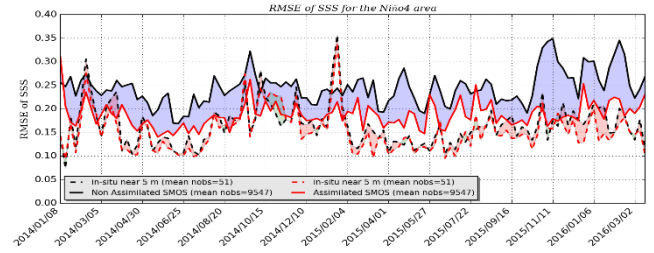
BGC Argo



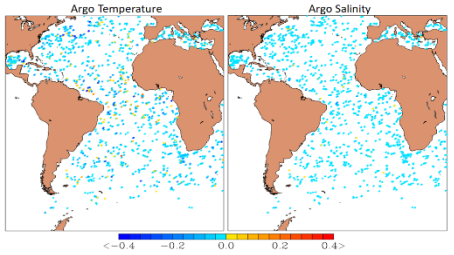
SKIM

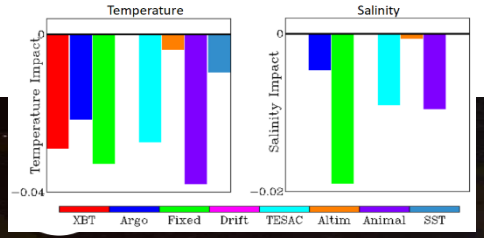


SMOS-NINO2015



Adjoint Sensitivity





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GODAE and GODAE OceanView provided special issues on their activities on "Oceanography" at 2009 and "Journal of Operational Oceanography" at 2014.